The Role of the GoldSim Model in the NorthMet Project

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What is the GoldSim model?

GoldSim is being used for water quantity and quality probabilistic modeling for the NorthMet project. Still have questions, huh? Let's start at the beginning.

A ***mathematical model*** is a set of equations used to simulate the behavior of a real physical system. Many tools have been developed to help with these mathematical simulations. Some tools are highly specialized to solving a particular type of problem. For example, MODFLOW has been developed to simulate groundwater flow and has the necessary equations built into it. Other tools are not specific to a particular type of problem but are capable of simulating a wide variety of systems. A spreadsheet is a good example of such a tool. Groundwater flow can be modeled using a spreadsheet, but the user has to enter the necessary equations. GoldSim falls into this group and can even be thought of as a fancy spreadsheet. It can be used to simulate a variety of systems and requires the user to enter equations that describe the system being modeled. GoldSim is a tool or "modeling platform" for building mathematical models of systems that can be used to simulate their behavior.

How is GoldSim being used for the NorthMet Project?

The modeling of water quality for the NorthMet Project is complicated because there are many sub-systems to represent. Think of the simple example of water quality in a river downhill from a stockpile (see Figure 1). First, the geometry and construction of the stockpile need to be considered to figure out how much of the precipitation landing on the stockpile will make its way to the bottom. Then chemical calculations need to be performed to determine how the quality of this water will change as it flows through the stockpile. Only a small amount of the water that reaches the bottom will leak through the stockpile liner into the ground. The liner leakage water that flows through the ground mixes with precipitation making its way into the ground (recharge) along its flow path and eventually discharges into the river. The groundwater which contains the leakage and the recharge is modeled using groundwater flow equations like those built into MODFLOW.

This system was modeled for the DEIS using several modeling tools. There was a spreadsheet model to represent the water flow through the stockpile, a spreadsheet model to evaluate the change in chemistry of the water as it moved through the stockpile, a model to determine how much water would leak through the liner (HELP - a standard landfill modeling tool), a groundwater flow model (MODFLOW), and a spreadsheet model to represent the river. For the SDEIS, most of this can be modeled using a single tool, GoldSim.

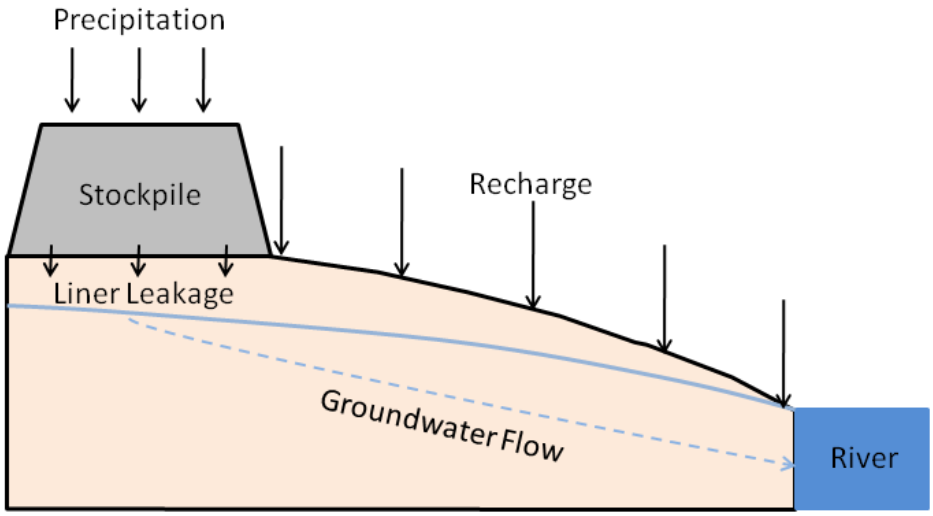

Figure 1 Schematic of flow path from stockpile to river

Think back to how a mathematical model was defined; it is a set of equations used to simulate the behavior of a real physical system. In the case of the NorthMet Project, there are two "systems" being modeled: the Mine Site and the Process Plant/Tailings Basin. For some parts of these systems, the same mathematical models (equations) that were used for the DEIS will be used for the SDEIS, but the tool used to build the model will be different. The water flow through the stockpile is a good example. The same equations will be used to determine how much precipitation will make its way to the bottom of the stockpile. For the DEIS, these equations were put into Excel. For the SDEIS, these equations will be put into GoldSim… same mathematical model, just a different tool. For some parts of the system, different mathematical models will be used either because the same equations can't be put into GoldSim or because the technical experts have agreed on a better way to simulate the system. The model of groundwater flow is a good example of the former. The equations that were used in the DEIS (MODFLOW) can't directly be used in GoldSim, so different equations that technical experts agree properly represent the system will be used.

So all water modeling is now being done in GoldSim?

Well, not exactly. The water balances and water quality models will all be built within GoldSim. But a lot of other models, built using different tools, will also be used. For example, the water flow in the Partridge River is still being simulated using XP-SWMM, as it was for the DEIS. A groundwater model of the tailings basin is again being used to estimate how much seepage there will be from the basin. In most cases, output from these other models is used as input into the models built in GoldSim. For example, the HELP model is still used to determine how much water would leak through a stockpile liner under various conditions, which is then used as an input to the GoldSim model.

The GoldSim model will be used to make the following estimates:

- The water balance for the Tailings Basin, including the amount of make-up water needed from Colby Lake;
- The quality of groundwater downstream from the Tailings Basin;
- The quality of water in the Embarrass River and its tributaries;
- The water balance for the Mine Pits, including how much time it will take for the West Pit to flood with water after mining is complete;
- The quality of groundwater downstream from stockpiles and pits; and
- The quality of water in the Partridge River.

Figures 2 and 3 show the difference in the number of separate mathematical models used between the work that was done for the DEIS and the work being done for the SDEIS for the Mine Site and Process Plant/Tailings Basin respectively. Each box represents an individual mathematical model, either a spreadsheet model or a model built using a different tool. It isn't necessary to understand the role or function of each modeling tool shown in the figures, but the idea is that a lot of different tools are used to make water quantity and quality estimates. For the SDEIS, all of the models shown as green boxes in the DEIS portion are included in the GoldSim model.

What's a "probabilistic model"?

Recall that a mathematic model is a set of equations used to simulate the behavior of a real physical system. When most people think of a mathematical model, they think of a ***deterministic model***, which assumes a single value for each input parameter. Consider the simple model shown by Equation 1 to calculate the amount of precipitation falling on an area that will make it into the groundwater below (i.e. the amount of recharge). This model is built on the assumption that 10% of the precipitation on that type of area makes it into the groundwater.

Mathematical Model: $Recharge = \frac{1}{10} \times Precipitation \times Area$ (Equation 1)

If it is assumed that *Precipitation* is 29 inches per year and *Area* is 1000 square inches, *Recharge* will be 290 cubic inches a year based on this mathematical model. Because *Precipitation* and *Area* are assumed to be single values, this is a deterministic model and *Recharge* will be a single value. But what if *Recharge* needs to be estimated in a future year when the exact amount of annual precipitation is unknown, although history shows it is likely to be between 22 and 32 inches? To recognize the potential range in annual precipitation, a ***probabilistic mathematical model*** can be used. A probabilistic model allows specification of a ***probability distribution*** for model inputs where a single value can't be assigned. A probability distribution is a mathematical representation of the relative likelihood of a model input having a specific value, which can be based on field or lab data, first principle relationships, empirical observations, professional judgment, or some combination of these.

A probabilistic modeling tool like GoldSim executes the model equations many times with model inputs randomly selected from the probability distributions and generates a probability distribution of model output values rather than the single value generated by a deterministic model. In Equation 1, depending on the probability distribution that is assigned to *Precipitation* and assuming that *Area* is still a single value of 1000 square inches, the probabilistic model output would be a probability distribution curve from which conclusions like "there is a 20% chance that recharge will be more than 310 cubic inches" could be drawn. For the NorthMet project, because not all of the model inputs can be properly represented as single values, the water quality/quantity modeling will be done using probabilistic models.

Why is there "uncertainty"?

There are two reasons that single value inputs may not be a proper representation of the actual physical system being modeled – variability and uncertainty. Consider again Equation 1, but replace the factor 1/10 with factor *X* to indicate that the percentage of the precipitation on that type of area that makes it into the groundwater is not precisely known.

Mathematical Model: $Recharge = X \times Precipitation \times Area$ (Equation 2)

In Equation 1, the precipitation in any given year is unknown because of the natural variability in precipitation; **variability** means that something varies over time or space and cannot be described with a single value. The observed precipitation record can be used to define a probability distribution for *Precipitation*.

Uncertainty means that the true value exists, but that value cannot be adequately determined. If there were extensive field data and detailed studies for the area in question, it would be technically possible to adequately determine the value for *X* for a given location. Then Equation 1 could be used. If there isn't sufficient field data or detailed studies to adequately define *X*, a probability distribution can be used to represent the uncertainty in the value of *X* based on available information.

The probabilistic model built in GoldSim recognizes the effects of both variability and uncertainty in the inputs to the system being modeled by allowing inputs to be defined as probability distributions. Outputs from other modeling tools (like MODFLOW) along with field or lab data, first principle relationships, empirical observations, professional judgment, or some combination of these can be used for this definition.

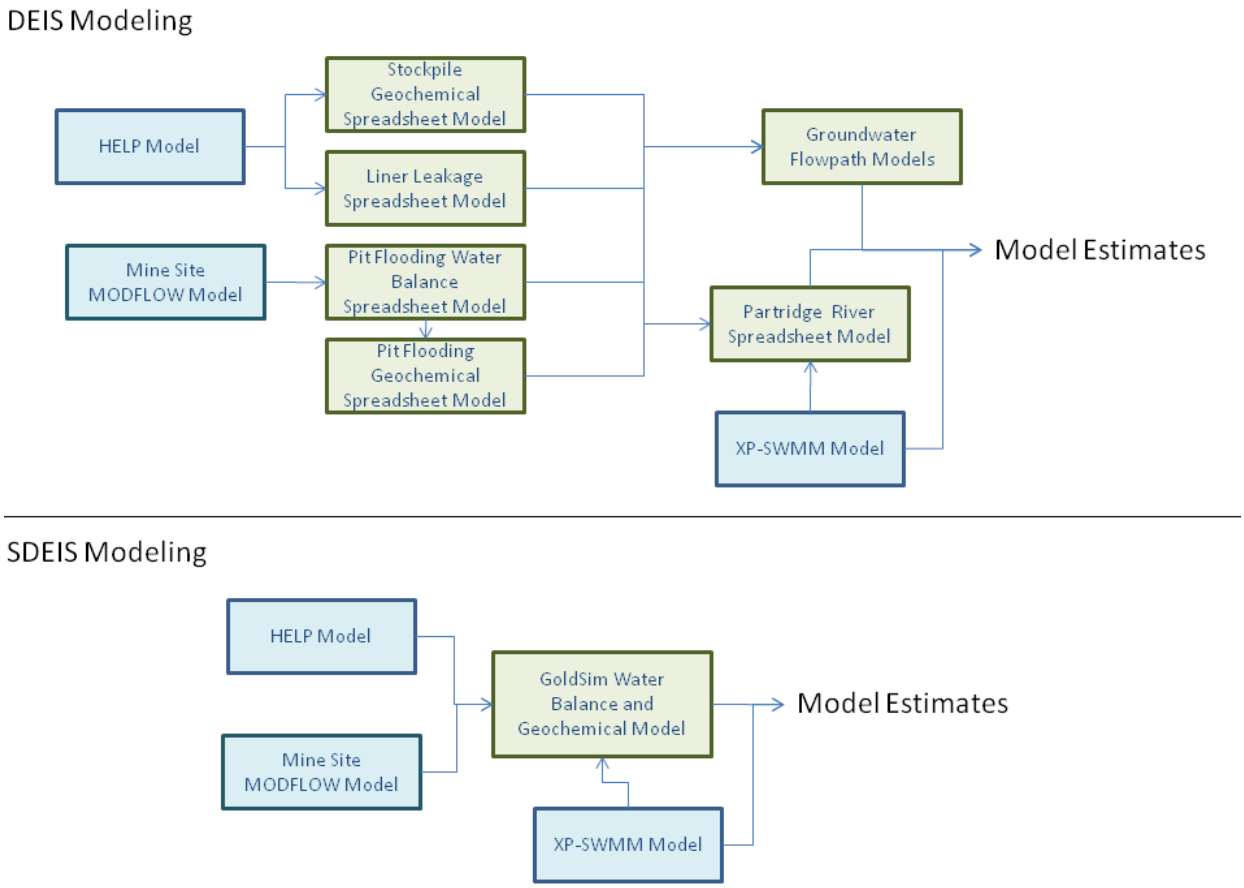

Figure 2 **DEIS versus SDEIS modeling for the Mine Site**

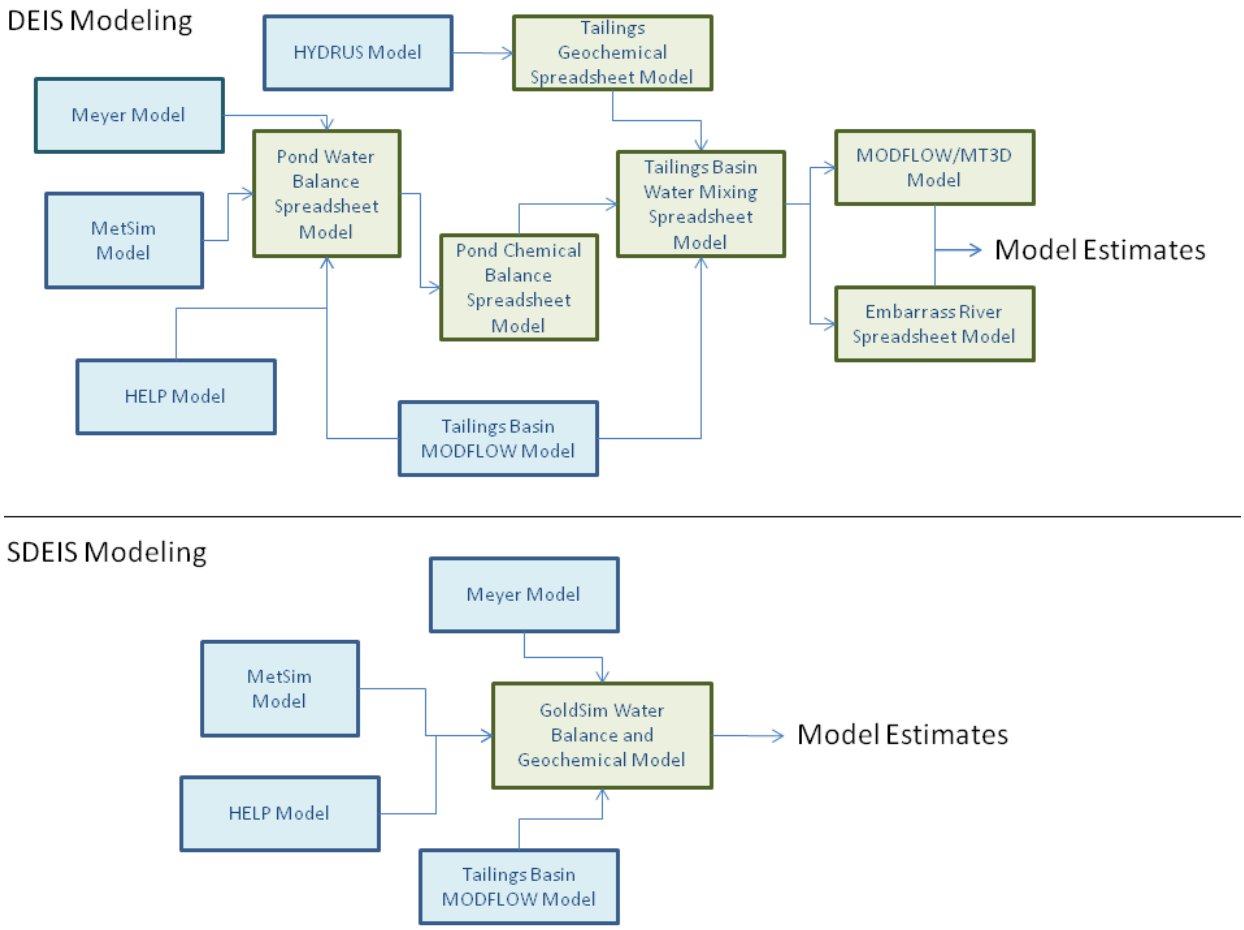

Figure 3 **DEIS versus SDEIS modeling for the Tailings Basin**